APPENDIX G
HAND CALCULATIONS FOR BENZENE

This example presents hand-calculations to verify the Tier 1 RBSLs for benzene. Note that calculations are shown for both the non-carcinogenic and carcinogenic effects for benzene. Tier 1 RBSL for a chemical with carcinogenic and non-carcinogenic toxicity is the lower of the carcinogenic and non-carcinogenic RBSLs.

Note: Calculations presented here were performed using Tier 1 default input parameters listed in the beginning of this appendix with the exception of the values used for θ_{ws}, θ_{wcrack}, θ_{as}, and θ_{acrack}. The value used for θ_{ws} and θ_{wcrack} is 0.1 as compared to the default value of 0.2. The value used for θ_{as} and θ_{acrack} is 0.2 as compared to the default value of 0.1. Note that these calculations are for illustration and may not reproduce the Tier 1 RBSLs for all pathways. However, the computational software will reproduce RBSLs calculated here if all the input values in the software are set the same as those used here.

APPENDIX G

This example presents hand-calculations to verify the Tier 1 RBSLs for benzene and receptors. Note calculations are shown for both the non-carcinogenic and carcinogenic effects for benzene.

Note to develop Tier 2A levels, the same calculations have to be repeated using site-specific inputs.

HAND CALCULATIONS
Contaminant: Benzene

1. Resident – Child
    a. Carcinogen
        i. Surficial Soil
        ii. Subsurface Soil
        iii. Groundwater
        iv. Soil to Groundwater (assuming DAF = 1)
    b. Non-Carcinogen
        i. Surficial Soil
        ii. Subsurface Soil
        iii. Groundwater

2. Resident – Adult
    a. Carcinogen
        i. Surficial Soil
        ii. Subsurface Soil
        iii. Groundwater
        iv. Soil to Groundwater (assuming DAF = 1)
    b. Non-Carcinogen
        i. Surficial Soil
        ii. Subsurface Soil
        iii. Groundwater

3. Commercial
    a. Carcinogen
        i. Surficial Soil
        ii. Subsurface Soil
        iii. Groundwater
        iv. Soil to Groundwater (assuming DAF = 1)
    b. Non-Carcinogen
        i. Surficial Soil
        ii. Subsurface Soil
        iii. Groundwater

Variables			Values Used*
$RBTL_{ss}$	=	Risk-based target level in surficial soil [mg/kg]	
TR	=	Target risk or the increased chance of developing cancer over a lifetime due to exposure to a chemical [-]	= 1e-6
BW	=	Body weight [kg]	= 15**
AT_c	=	Averaging time for carcinogens [years]	= 70
ED	=	Exposure duration [years]	= 6**
EF	=	Exposure frequency [days/year]	= 350**
IR_{soil}	=	Soil ingestion rate [mg/day]	= 200**
RAF_o	=	Oral relative absorption factor [-]	= 1
SA	=	Skin surface area [cm^2/day]	= 2500**
M	=	Soil to skin adherence factor [mg/cm^2]	= 0.15
RAF_d	=	Dermal relative absorption factor [-]	= 0.5
IR_{ao}	=	Outdoor inhalation rate [m^3/hr]	= 1**
ET_{out}	=	Outdoor Exposure time [hr/day]	= 10
SF_o	=	Oral cancer slope factor [(mg/kg-day)$^{-1}$]	= 0.055
SF_i	=	Inhalation cancer slope factor [(mg/kg-day)$^{-1}$]	= 0.029
RfD_o	=	The chemical-specific oral reference dose [(mg/kg-day)]	= 0.003
RfD_i	=	The chemical-specific inhalation reference dose [(mg/kg-day)]	= 0.0017
P_e	=	Particulate emission rate [g-soil/cm^2-sec]	= 6.90e-14
W_a	=	Length of soil source area parallel to wind direction [cm]	= 1500
U_a	=	Wind speed at δ_a above ground surface [cm/s]	= 225
δ_a	=	Breathing zone height [cm]	= 200
VF_p	=	Volatilization factor of particulates [(mg/m^3-air)/(mg/kg-soil)]	
ρ_s	=	Dry soil bulk density [g-soil/cm^3-soil]	= 1.8
D^a	=	Chemical-specific diffusion coefficient in air [cm^2/s]	= 9.30e-2
D^w	=	Chemical-specific diffusion coefficient in water [cm^2/s]	= 1.10e-5
θ_{as}	=	Volumetric air content in vadose zone [cm^3-air/cm^3-soil]	= 0.2
θ_{ws}	=	Volumetric water content in vadose zone [cm^3-H_2O/cm^3-soil]	= 0.1
θ_T	=	Total soil porosity in the impacted zone [cm^3/cm^3-soil]	= 0.3
H	=	Chemical-specific Henry's Law constant [(mg/cm^3-air)/ (mg/cm^3-H_2O)]	= 0.228
D_s^{eff}	=	Effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s]	
K_s	=	$f_{oc} \times K_{oc}$	
	=	Chemical-specific soil-water sorption coefficient for the unsaturated zone [cm^3-H_2O/g-soil]	= 0.661
τ	=	Averaging time for vapor flux [s]	
	=	$ED\ (yr) \times 365\ (day/yr) \times 86400\ (sec/day)$	= 1.89e8**
d	=	Depth to base of surficial soil zone [cm]	= 30.48
VF_{ss}	=	Volatilization factor from surficial soil [(mg/m^3-air)/(mg/kg-soil)]	
$RBTL_{si}$	=	Risk-based target level for indoor inhalation of vapors from subsurface soils [mg/kg-soil]	
IR_{ai}	=	Indoor inhalation rate [m^3/hr]	= 0.417**

ET_{in}	=	Indoor Exposure time [hr/day]	= 18**
$RBTL_{ai}$	=	Risk-based target level for indoor inhalation of air [mg/m^3-air]	
L_s	=	Depth to subsurface soil sources [cm]	= 30.48
L_B	=	Enclosed space volume/infiltration area ratio [cm]	= 200**
L_{crack}	=	Enclosed space foundation or wall thickness [cm]	= 15
ER	=	Enclosed space air exchange rate [1/s]	= 0.00014**
θ_{acrack}	=	Volumetric air content in foundation/wall cracks [cm^3-air/cm^3-total volume]	= 0.2
θ_{wcrack}	=	Volumetric water content in foundation/wall cracks [cm^3-H_2O/cm^3-total volume]	= 0.1
D_{crack}^{eff}	=	Effective diffusion coefficient through foundation cracks [cm^2/s]	
h	=	Areal fraction of cracks in foundation and/or walls [cm^2-cracks/ cm^2-total area]	= 0.01
VF_{sesp}	=	Volatilization factor from subsurface soil to indoor (enclosed space) air [(mg/m^3-air)/(mg/kg-soil)]	
$RBTL_{wi}$	=	Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O]	
L_{GW}	=	Depth to groundwater [cm]	= 300
h_{cap}	=	Thickness of capillary fringe [cm]	= 5
h_v	=	Thickness of vadose zone [cm]	= 295
θ_{acap}	=	Volumetric air content in capillary fringe soils [cm^3-air/cm^3-soil]	= 0.03
θ_{wcap}	=	Volumetric water content in capillary fringe soils [cm^3-H_2O/cm^3-soil]	= 0.27
D_{cap}^{eff}	=	Effective diffusion coefficient through capillary fringe [cm^2/s]	
D_{ws}^{eff}	=	Effective diffusion coefficient between groundwater and soil surface [cm^2/s]	
VF_{wesp}	=	Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-H_2O)]	
Target surface water Concentration [mg/L]			= 0.005
DAF_{POE}	=	Dilution Attenuation Factor between the point of exposure and the source [-]	= 1
U_{gw}	=	Groundwater Darcy Velocity [cm/year]	= 304
d_{gw}	=	Groundwater mixing zone thickness [cm]	= 200
I	=	Infiltration rate of water through soil [cm/year]	= 14
W	=	Length of source area parallel to groundwater flow [cm]	= 1500
LF_{sw}	=	Dry soil leaching factor [(mg/L-H_2O)/(mg/kg-soil]	
THQ	=	Target hazard quotient for individual constituents [-]	= 1
AT_{nc}	=	Averaging time for non-carcinogens [years]	= 6**
$RBTL_{ss}$	=	Risk-based target level in surficial soil [mg/kg]	

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* Values are not listed for calculated variables.

** Values may change for different receptors.

1. **Resident – Child**
    a. **Carcinogen**
        i. **Surficial Soil**

$$RBTL_{SS}=\frac{TR\times BW\times AT_c\times 365}{EF\times ED\times[(SF_o\times 10^{-6}\times(IR_{soil}\times RAF_o+SA\times M\times RAF_d))+(SF_i\times IR_{ao}\times ET_{out}\times(VF_{SS}+VF_p))]}$$

$$VF_p=\frac{P_e\times W_a}{U_a\times\delta_a}\times 10^3$$

$$VF_p=\frac{6.9e-14\times 1500}{225\times 200}\times 10^3=2.30e-12$$

VF_p = Volatilization factor of particulates [(mg/m^3-air)/(mg/kg-soil)] = 2.30e-12

$$VF_{ss}=\frac{2\times W_a\times\rho_s}{U_a\times\delta_a}\times\sqrt{\frac{D_s^{eff}\times H}{\pi\times[\theta_{ws}+(K_s\times\rho_s)+(H\times\theta_{as})]\times\tau}}\times 10^3$$

$$D_s^{eff}=D^a\times\frac{\theta_{as}^{3.33}}{\theta_T^{2.0}}+D^w\times\frac{1}{H}\times\frac{\theta_{ws}^{3.33}}{\theta_T^{2.0}}$$

$$D_s^{eff}=9.30e-2\times\frac{0.2^{3.33}}{0.3^2}+1.10e-5\times\frac{1}{0.228}\times\frac{0.1^{3.33}}{0.3^2}=4.86e-3$$

D_s^{eff} = Effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s] = 4.86e-3

$$(i)VF_{ss}=\frac{2\times W_a\times\rho_s}{U_a\times\delta_a}\times\sqrt{\frac{D_s^{eff}\times H}{\pi\times[\theta_{ws}+(K_s\times\rho_s)+(H\times\theta_{as})]\times\tau}}\times 10^3$$

$$(i)VF_{ss}=\frac{2\times 1500\times 1.8}{225\times 200}\times\sqrt{\frac{4.86E-3\times 0.228}{\pi\times[0.1+(0.661\times 1.8)+(0.228\times 0.2)]\times 1.89E8}}\times 10^3=1.419E-4$$

$$(ii)VF_{ss}=\frac{W_a\times\rho_s\times d}{U_a\times\delta_a\times\tau}\times 10^3$$

$$(ii)VF_{ss}=\frac{1500\times 1.8\times 30.48}{225\times 200\times 1.89E8}\times 10^3=9.68E-6$$

** Take smaller of the two values:

VF_{ss} = Volatilization factor from surficial soil [(mg/m^3-air)/(mg/kg-soil)] = 9.68e-6

$$RBTL_{SS} = \frac{1e-6 \times 15 \times 70 \times 365}{350 \times 6 \times [(0.055 \times 10^{-6} \times (200 \times 1 + 2500 \times 0.15 \times 0.5)) + (0.029 \times 1 \times 10 \times (9.68e-6 + 2.30e-12))]} = 7.57$$

ii. Subsurface Soil

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{TR \times BW \times AT_c \times 365}{IR_{ai} \times ET_{in} \times ED \times EF \times SF_i}$$

$$RBTL_{ai} = \frac{1e\text{-}6 \times 15 \times 70 \times 365}{0.417 \times 18 \times 6 \times 350 \times 0.029} = 8.38e-4$$

$RBTL_{ai}$ = Risk-based target level for indoor inhalation of air [mg/m^3-air] = 8.38e-4

$$VF_{sesp} = \frac{\frac{H \times \rho_s}{[\theta_{ws} + (K_s \times \rho_s) + (H \times \theta_{as})]} \times \left[\frac{D_s^{eff} / L_s}{ER \times L_B}\right]}{1 + \left[\frac{D_s^{eff} / L_s}{ER \times L_B}\right] + \left[\frac{D_s^{eff} / L_s}{(D_{crack}^{eff} / L_{crack}) \times h}\right]} \times 10^3$$

$$D_{crack}^{eff} = D^a \times \frac{\theta_{acrack}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^{2.0}}$$

$$D_{crack}^{eff} = 9.30e-2 \times \frac{0.2^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.1^{3.33}}{0.3^2} = 4.861e-3$$

D_{crack}^{eff} = Effective diffusion coefficient through foundation cracks [cm^2/s] = 4.861e-3

$$VF_{sesp} = \frac{\frac{0.228 \times 1.8}{0.1 + (0.661 \times 1.8) + (0.228 \times 0.2)} \times \left[\frac{4.86e-3/30.48}{0.00014 \times 200}\right]}{1 + \left[\frac{4.86e-3/30.48}{0.00014 \times 200}\right] + \left[\frac{4.86e-3/30.48}{(4.86e-3/15) \times 0.01}\right]} \times 10^3 = 3.485e-2$$

VF_{sesp} = Volatilization factor from subsurface soil to indoor (enclosed space) air [(mg/m^3-air)/(mg/kg-soil)] = 3.485e-2

$$RBTL_{si} = \frac{8.38e-4}{3.49e-2} = 2.4e-2$$

iii. Groundwater

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$VF_{wesp} = \frac{H \times \left[\frac{D_{ws}^{eff}/L_{GW}}{ER \times L_B}\right]}{1 + \left[\frac{D_{ws}^{eff}/L_{GW}}{ER \times L_B}\right] + \left[\frac{D_{ws}^{eff}/L_{GW}}{(D_{crack}^{eff}/L_{crack}) \times h}\right]} \times 10^3$$

$$D_{ws}^{eff} = (h_{cap} + h_v) \times \left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1}$$

$$D_{cap}^{eff} = D^a \times \frac{\theta_{acap}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcap}^{3.33}}{\theta_T^{2.0}}$$

$$D_{cap}^{eff} = 9.30e-2 \times \frac{0.03^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.27^{3.33}}{0.3^2} = 1.562e-5$$

D_{cap}^{eff} = Effective diffusion coefficient through capillary fringe [cm^2/s] = 1.56e-5

$$D_{ws}^{eff} = (5 + 295) \times \left[\frac{5}{1.56e-5} + \frac{295}{4.86e-3}\right]^{-1} = 7.88e-4$$

D_{ws}^{eff} = Effective diffusion coefficient between groundwater and soil surface [cm^2/s] = 7.88e-4

$$VF_{wesp} = \frac{0.228 \times \left[\frac{7.88e-4/300}{0.00014 \times 200}\right]}{1 + \left[\frac{7.88e-4/300}{0.00014 \times 200}\right] + \left[\frac{7.88e-4/300}{(4.86e-3/15) \times 0.01}\right]} \times 10^3 = 1.181e-2$$

VF_{wesp} = Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-H_2O)] = 1.18e-2

$$RBTL_{wi} = \frac{8.38e-4}{1.18e-2} = 7.095e-2$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 7.10e-2

iv. Soil to Groundwater

$$\text{Allowable soil concentration at the source}[\text{mg/kg}] = \textit{Target surface water concentration}[\text{mg/L}]\ \textit{at the POE} \times \frac{DAF_{POE}}{LF_{SW}}$$

$$LF_{SW} = \frac{\rho_s}{[\theta_{ws} + K_s \times \rho_s + H \times \theta_{as}] \times \left(1 + \frac{U_{gw} \times \delta_{gw}}{I \times W}\right)}$$

$$LF_{SW} = \frac{1.8}{[0.1 + 0.661 \times 1.8 + 0.228 \times 0.2] \times \left(1 + \frac{304 \times 200}{14 \times 1500}\right)} = 0.346$$

LF_{sw} = Dry soil leaching factor [(mg/L-H_2O)/(mg/kg-soil] = 0.346

$$\text{Allowable soil concentration at the source}[\text{mg/kg}] = 0.005 \times \frac{1}{0.346} = 1.449e-2$$

b. Non-Carcinogen

i. Surficial Soil

$$RBTL_{SS} = \frac{THQ \times BW \times AT_{nc} \times 365}{EF \times ED \times \left[\frac{10^{-6} \times (IR_{soil} \times RAF_o + SA \times M \times RAF_d)}{RfD_o} + \frac{(ET_{out} \times IR_{ao} \times (VF_{ss} + VF_p))}{RfD_i} \right]}$$

$$RBTL_{SS} = \frac{1 \times 15 \times 6 \times 365}{350 \times 6 \times \left[\frac{10^{-6} \times (200 \times 1 + 2500 \times 0.15 \times 0.5)}{0.003} + \frac{(10 \times 1 \times (9.67e-6 + 2.30e-12))}{0.0017} \right]} = 84.079$$

$RBTL_{ss}$ = Risk-based target level in surficial soil [mg/kg] = 84.079

ii. Subsurface

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_i}{IR_{ai} \times ET_{in} \times ED \times EF}$$

$$RBTL_{ai} = \frac{1 \times 15 \times 6 \times 365 \times 0.0017}{0.417 \times 18 \times 6 \times 350} = 3.543e-3$$

$RBTL_{ai}$ = Risk-based target level in indoor air [mg/m^3] = 3.543e-3

$$RBTL_{si} = \frac{3.543e-3}{3.485e-2} = 1.017e-1$$

$RBTL_{si}$ = Risk-based target level for indoor inhalation of vapors from subsurface soils [mg/kg-soil] = 1.017e-1

iii. Groundwater

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$RBTL_{wi} = \frac{3.543e-3}{1.181e-2} = 0.30$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 0.30

2. Resident – Adult

Variables		Values Used
BW	= Body weight [kg]	= 70**
ED	= Exposure duration [years]	= 30**
EF	= Exposure frequency [days/year]	= 350**
IR_{soil}	= Soil ingestion rate [mg/day]	= 100**
SA	= Skin surface area [cm^2/day]	= 5000**
IR_{ao}	= Outdoor inhalation rate [m^3/hr]	= 1.5**
τ	= averaging time for vapor flux,	
	$ED\ (yr) \times 365\ (day/yr) \times 86400\ (sec/day)$	= 7.88e8**
IR_{ai}	= Indoor inhalation rate [m^3/hr]	= 0.633**
ET_{in}	= Indoor Exposure time [hr/day]	= 18**
L_B	= Enclosed space volume/infiltration area ratio [cm]	= 200**
ER	= Enclosed space air exchange rate [1/s]	= 0.00014**
AT_{nc}	= Averaging time for non-carcinogens [years]	= 30**

**Values may change for different receptors.

a. Carcinogen

i. Surficial Soil

$$RBTL_{SS} = \frac{TR \times BW \times AT_c \times 365}{EF \times ED \times [(SF_o \times 10^{-6} \times (IR_{soil} \times RAF_o + SA \times M \times RAF_d)) + (SF_i \times IR_{ao} \times ET_{out} \times (VF_{SS} + VF_p))]}$$

$$VF_p = \frac{P_e \times W_a}{U_a \times \delta_a} \times 10^3$$

$$VF_p = \frac{6.9e-14 \times 1500}{225 \times 200} \times 10^3 = 2.30e-12$$

VF_p = Volatilization factor of particulates [$(mg/m^3$-air)/(mg/kg-soil)] = 2.30e-12

$$(i)VF_{ss} = \frac{2 \times W_a \times \rho_s}{U_a \times \delta_a} \times \sqrt{\frac{D_s^{eff} \times H}{\pi \times [\theta_{ws} + (K_s \times \rho_s) + (H \times \theta_{as})] \times \tau}} \times 10^3$$

$$D_s^{eff} = D^a \times \frac{\theta_{as}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{ws}^{3.33}}{\theta_T^{2.0}}$$

$$D_s^{eff} = 9.30e-2 \times \frac{0.2^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.1^{3.33}}{0.3^2} = 4.86e-3$$

D_s^{eff} = Effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s] = 4.86e-3

$$(i)VF_{ss} = \frac{2\times 1500\times 1.8}{225\times 200}\times\sqrt{\frac{4.86e-3\times 0.228}{\pi\times[0.1+(0.661\times 1.8)+(0.228\times 0.2)]\times 9.46E8}}\times 10^{3} = 6.342e-5$$

$$(ii)VF_{ss} = \frac{W_a\times\rho_s\times d}{U_a\times\delta_a\times\tau}\times 10^{3}$$

$$(ii)VF_{ss} = \frac{1500\times 1.8\times 30.48}{225\times 200\times 1.89E8}\times 10^{3} = 1.933e-6$$

** Take smaller of the two values:

VF_{ss} = Volatilization factor from surficial soil [(mg/m^3-air)/(mg/kg-soil)] = 1.93e-6

$$RBTL_{SS} = \frac{1e-6\times 70\times 70\times 365}{350\times 30\times[(0.055\times 10^{-6}\times(100\times 1+5000\times 0.15\times 0.5))+(0.029\times 1.5\times 10\times(1.93e-6+2.30e-12))]} = 6.318$$

ii. Subsurface Soil

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{TR\times BW\times AT_c\times 365}{IR_{ai}\times ET_{in}\times ED\times EF\times SF_i}$$

$$RBTL_{ai} = \frac{1e-6\times 70\times 70\times 365}{0.633\times 18\times 30\times 350\times 0.029} = 5.155e-4$$

$RBTL_{ai}$ = Risk-based target level for indoor inhalation of air [mg/m^3-air] = 5.15e-4

$$VF_{sesp} = \frac{\frac{H\times\rho_s}{[\theta_{ws}+(K_s\times\rho_s)+(H\times\theta_{as})]}\times\left[\frac{D_s^{eff}/L_s}{ER\times L_B}\right]}{1+\left[\frac{D_s^{eff}/L_s}{ER\times L_B}\right]+\left[\frac{D_s^{eff}/L_s}{(D_{crack}^{eff}/L_{crack})\times h}\right]}\times 10^{3}$$

$$D_{crack}^{eff} = D^a \times \frac{\theta_{acrack}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^{2.0}}$$

$$D_{crack}^{eff} = 9.30e-2 \times \frac{0.2^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.1^{3.33}}{0.3^2} = 4.861e-3$$

D_{crack}^{eff} = Effective diffusion coefficient through foundation cracks [cm^2/s] = 4.861e-3

$$VF_{sesp} = \frac{\frac{0.228 \times 1.8}{0.1 + (0.661 \times 1.8) + (0.228 \times 0.2)} \times \left[\frac{4.86e-3/30.48}{0.00014 \times 200}\right]}{1 + \left[\frac{4.86e-3/30.48}{0.00014 \times 200}\right] + \left[\frac{4.86e-3/30.48}{(4.86e-3/15) \times 0.01}\right]} \times 10^3 = 3.485e-2$$

VF_{sesp} = Volatilization factor from subsurface soil to indoor (enclosed space) air [$(mg/m^3\text{-air})/(mg/kg\text{-soil})$] = 3.485e-2

$$RBTL_{si} = \frac{5.15e-4}{3.49e-2} = 1.479e-2$$

iii. Groundwater

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$VF_{wesp} = \frac{H \times \left[\frac{D_{ws}^{eff}/L_{GW}}{ER \times L_B}\right]}{1 + \left[\frac{D_{ws}^{eff}/L_{GW}}{ER \times L_B}\right] + \left[\frac{D_{ws}^{eff}/L_{GW}}{(D_{crack}^{eff}/L_{crack}) \times h}\right]} \times 10^3$$

$$D_{ws}^{eff} = (h_{cap} + h_v) \times \left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}}\right]^{-1}$$

$$D_{cap}^{eff} = D^a \times \frac{\theta_{acap}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcap}^{3.33}}{\theta_T^{2.0}}$$

$$D_{cap}^{eff} = 9.30e-2 \times \frac{0.03^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.27^{3.33}}{0.3^2} = 1.562e-5$$

D_{cap}^{eff} = Effective diffusion coefficient through capillary fringe [cm^2/s] = 1.56e-5

$$D_{ws}^{eff} = (5 + 295) \times \left[\frac{5}{1.56e-5} + \frac{295}{4.86e-3} \right]^{-1} = 7.88e-4$$

D_{ws}^{eff} = Effective diffusion coefficient between groundwater and soil surface [cm^2/s] = 7.88e-4

$$VF_{wesp} = \frac{0.228 \times \left[\frac{7.88e-4/300}{0.00014 \times 200} \right]}{1 + \left[\frac{7.88e-4/300}{0.00014 \times 200} \right] + \left[\frac{7.88e-4/300}{(4.86e-3/15) \times 0.01} \right]} \times 10^3 = 1.181e-2$$

VF_{wesp} = Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-H_2O)] = 1.18e-2

$$RBTL_{wi} = \frac{5.15e-4}{1.18e-2} = 4.36e-2$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 4.36e-2

iv. Soil to Groundwater

$$\text{Allowable soil concentration at the source [mg/kg]} = \textit{Target surface water concentration [mg/L] at the POE} \times \frac{DAF_{POE}}{LF_{SW}}$$

$$LF_{SW} = \frac{\rho_s}{[\theta_{ws} + K_s \times \rho_s + H \times \theta_{as}] \times \left(1 + \frac{U_{gw} \times \delta_{gw}}{I \times W} \right)}$$

$$LF_{SW} = \frac{1.8}{[0.1 + 0.661 \times 1.8 + 0.228 \times 0.2] \times \left(1 + \frac{304 \times 200}{14 \times 1500} \right)} = 0.346$$

LF_{sw} = Dry soil leaching factor [(mg/L-H_2O)/(mg/kg-soil] = 0.346

$$\text{Allowable soil concentration at the source}[\text{mg/kg}] = 0.005 \times \frac{1}{0.346} = 1.449e-2$$

b. Non-Carcinogen

i. Surficial Soil

$$RBTL_{SS} = \frac{THQ \times BW \times AT_{nc} \times 365}{EF \times ED \times \left[\frac{10^{-6} \times (IR_{soil} \times RAF_o + SA \times M \times RAF_d)}{RfD_o} + \frac{(ET_{out} \times IR_{ao} \times (VF_{ss} + VF_p))}{RfD_i} \right]}$$

$$RBTL_{SS} = \frac{1 \times 70 \times 30 \times 365}{350 \times 30 \times \left[\frac{10^{-6} \times (100 \times 1 + 5000 \times 0.15 \times 0.5)}{0.003} + \frac{(10 \times 1 \times (1.93e-6 + 2.30e-12))}{0.0017} \right]} = 4.302e2$$

$RBTL_{ss}$ = Risk-based target level in surficial soil [mg/kg] = 4.30e2

ii. Subsurface

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_i}{IR_{ai} \times ET_{in} \times ED \times EF}$$

$$RBTL_{ai} = \frac{1 \times 70 \times 30 \times 365 \times 0.0017}{0.633 \times 18 \times 30 \times 350} = 1.089e-2$$

$RBTL_{ai}$ = Risk-based target level in indoor air [mg/m^3] = 1.09e-2

$$RBTL_{si} = \frac{1.09e-2}{1.18e-2} = 9.24e-1$$

$RBTL_{si}$ = Risk-based target level for indoor inhalation of vapors from subsurface soils [mg/kg-soil] = 9.24e-1

iii. Groundwater

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$RBTL_{wi} = \frac{1.09e-2}{1.181e-2} = 0.924$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 0.92

3. Commercial

Variables			Values Used
BW	=	Body weight [kg]	= 70**
ED	=	Exposure duration [years]	= 25**
EF	=	Exposure frequency [days/year]	= 250**
IR_{soil}	=	Soil ingestion rate [mg/day]	= 50**
SA	=	Skin surface area [cm^2/day]	= 5000**
IR_{ao}	=	Outdoor inhalation rate [m^3/hr]	= 1.5**
τ	=	averaging time for vapor flux, $ED\ (yr) \times 365\ (day/yr) \times 86400\ (sec/day)$	= 7.88e8**
IR_{ai}	=	Indoor inhalation rate [m^3/hr]	= 1.5**
ET_{in}	=	Indoor Exposure time [hr/day]	= 10**
L_B	=	Enclosed space volume/infiltration area ratio [cm]	= 300**
ER	=	Enclosed space air exchange rate [1/s]	= 0.00023**
AT_{nc}	=	Averaging time for non-carcinogens [years]	= 25**

**Values may change for different receptors.

a. Carcinogen

i. Surficial Soil

$$RBTL_{SS}=\frac{TR\times BW\times AT_c\times 365}{EF\times ED\times[(SF_o\times 10^{-6}\times(IR_{soil}\times RAF_o+SA\times M\times RAF_d))+(SF_i\times IR_{ao}\times ET_{out}\times(VF_{SS}+VF_p))]}$$

$$VF_p=\frac{P_e\times W_a}{U_a\times\delta_a}\times 10^3$$

$$VF_p=\frac{6.9e-14\times 1500}{225\times 200}\times 10^3=2.30e-12$$

VF_p = Volatilization factor of particulates [(mg/m^3-air)/(mg/kg-soil)] = 2.30e-12

$$(i)VF_{ss}=\frac{2\times W_a\times\rho_s}{U_a\times\delta_a}\times\sqrt{\frac{D_s^{eff}\times H}{\pi\times[\theta_{ws}+(K_s\times\rho_s)+(H\times\theta_{as})]\times\tau}}\times 10^3$$

$$D_s^{eff}=D^a\times\frac{\theta_{as}^{3.33}}{\theta_T^{2.0}}+D^w\times\frac{1}{H}\times\frac{\theta_{ws}^{3.33}}{\theta_T^{2.0}}$$

$$D_s^{eff}=9.30e-2\times\frac{0.2^{3.33}}{0.3^2}+1.10e-5\times\frac{1}{0.228}\times\frac{0.1^{3.33}}{0.3^2}=4.86e-3$$

D_s^{eff} = Effective diffusion coefficient in soil based on vapor-phase

concentration [cm^2/s] = 4.86e-3

$$(i)VF_{ss} = \frac{2\times 1500\times 1.8}{225\times 200}\times\sqrt{\frac{4.86E-3\times 0.228}{\pi\times[0.1+(0.661\times 1.8)+(0.228\times 0.2)]\times 7.88E8}}\times 10^3 = 6.949E-5$$

$$(ii)VF_{ss} = \frac{W_a\times\rho_s\times d}{U_a\times\delta_a\times\tau}\times 10^3$$

$$(ii)VF_{ss} = \frac{1500\times 1.8\times 30.48}{225\times 200\times 7.88E8}\times 10^3 = 2.321E-6$$

** Take smaller of the two values:

VF_{ss} = Volatilization factor from surficial soil [$(mg/m^3$-air)/(mg/kg-soil)] = 2.32e-6

$$RBTL_{SS} = \frac{1e-6\times 70\times 70\times 365}{250\times 25\times[(0.055\times 10^{-6}\times(50\times 1+5000\times 0.15\times 0.5))+(0.029\times 1.5\times 10\times(2.32e-6+2.30e-12))]} = 11.735$$

ii. Subsurface Soil

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{TR\times BW\times AT_c\times 365}{IR_{ai}\times ET_{in}\times ED\times EF\times SF_i}$$

$$RBTL_{ai} = \frac{1e\text{-}6\times 70\times 70\times 365}{1.5\times 10\times 25\times 250\times 0.029} = 6.578e-4$$

$RBTL_{ai}$ = Risk-based target level for indoor inhalation of air [mg/m^3-air] = 6.578e-4

$$VF_{sesp} = \frac{\frac{H\times\rho_s}{[\theta_{ws}+(K_s\times\rho_s)+(H\times\theta_{as})]}\times\left[\frac{D_s^{eff}/L_s}{ER\times L_B}\right]}{1+\left[\frac{D_s^{eff}/L_s}{ER\times L_B}\right]+\left[\frac{D_s^{eff}/L_s}{(D_{crack}^{eff}/L_{crack})\times h}\right]}\times 10^3$$

$$D_{crack}^{eff} = D^a \times \frac{\theta_{acrack}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^{2.0}}$$

$$D_{crack}^{eff} = 9.30e-2 \times \frac{0.2^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.1^{3.33}}{0.3^2} = 4.861e-3$$

D_{crack}^{eff} = Effective diffusion coefficient through foundation cracks [cm^2/s] = 4.861e-3

$$VF_{sesp} = \frac{\frac{0.228 \times 1.8}{0.1 + (0.661 \times 1.8) + (0.228 \times 0.2)} \times \left[\frac{4.86e-3/30.48}{0.00023 \times 300} \right]}{1 + \left[\frac{4.86e-3/30.48}{0.00023 \times 300} \right] + \left[\frac{4.86e-3/30.48}{(4.86e-3/15) \times 0.01} \right]} \times 10^3 = 1.414e-2$$

VF_{sesp} = Volatilization factor from subsurface soil to indoor (enclosed space) air [(mg/m^3-air)/(mg/kg-soil)] = 1.41e-2

$$RBTL_{si} = \frac{6.58e-4}{1.41e-2} = 4.65e-2$$

iii. Groundwater

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$VF_{wesp} = \frac{H \times \left[\frac{D_{ws}^{eff} / L_{GW}}{ER \times L_B} \right]}{1 + \left[\frac{D_{ws}^{eff} / L_{GW}}{ER \times L_B} \right] + \left[\frac{D_{ws}^{eff} / L_{GW}}{(D_{crack}^{eff} / L_{crack}) \times h} \right]} \times 10^3$$

$$D_{ws}^{eff} = (h_{cap} + h_v) \times \left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}} \right]^{-1}$$

$$D_{cap}^{eff} = D^a \times \frac{\theta_{acap}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcap}^{3.33}}{\theta_T^{2.0}}$$

$$D_{cap}^{eff} = 9.30e-2 \times \frac{0.03^{3.33}}{0.3^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.27^{3.33}}{0.3^2} = 1.562e-5$$

D_{cap}^{eff} = Effective diffusion coefficient through capillary fringe [cm^2/s] = 1.56e-5

$$D_{ws}^{eff} = (5 + 295) \times \left[\frac{5}{1.56e-5} + \frac{295}{4.86e-3} \right]^{-1} = 7.88e-4$$

D_{ws}^{eff} = Effective diffusion coefficient between groundwater and soil surface [cm^2/s] = 7.88e-4

$$VF_{wesp} = \frac{0.228 \times \left[\frac{7.88e-4/300}{0.00023 \times 300} \right]}{1 + \left[\frac{7.88e-4/300}{0.00023 \times 300} \right] + \left[\frac{7.88e-4/300}{(4.86e-3/15) \times 0.01} \right]} \times 10^3 = 4.793e-3$$

VF_{wesp} = Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-H_2O)] = 4.793e-3

$$RBTL_{wi} = \frac{6.58e-4}{4.793e-3} = 1.372e-1$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 1.37e-1

iv. Soil to Groundwater

$$\text{Allowable soil concentration at the source}[\text{mg/kg}] = \textit{Target surface water concentration}[\text{mg/L}]\ \textit{at the POE} \times \frac{DAF_{POE}}{LF_{SW}}$$

$$LF_{SW} = \frac{\rho_s}{[\theta_{ws} + K_s \times \rho_s + H \times \theta_{as}] \times \left(1 + \frac{U_{gw} \times \delta_{gw}}{I \times W} \right)}$$

$$LF_{SW} = \frac{1.8}{[0.1 + 0.661 \times 1.8 + 0.228 \times 0.2] \times \left(1 + \frac{304 \times 200}{14 \times 1500} \right)} = 0.346$$

LF_{sw} = Dry soil leaching factor [(mg/L-H_2O)/(mg/kg-soil] = 0.346

$$\text{Allowable soil concentration at the source}[\text{mg/kg}] = 0.005 \times \frac{1}{0.346} = 1.449e-2$$

b. Non-Carcinogen

i. Surficial Soil

$$RBTL_{SS} = \frac{THQ \times BW \times AT_{nc} \times 365}{EF \times ED \times \left[\frac{10^{-6} \times (IR_{soil} \times RAF_o + SA \times M \times RAF_d)}{RfD_o} + \frac{(ET_{out} \times IR_{ao} \times (VF_{ss} + VF_p))}{RfD_i} \right]}$$

$$RBTL_{SS} = \frac{1 \times 70 \times 25 \times 365}{250 \times 25 \times \left[\frac{10^{-6} \times (50 \times 1 + 5000 \times 0.15 \times 0.5)}{0.003} + \frac{(10 \times 1 \times (2.32e-6 + 2.30e-12))}{0.0017} \right]} = 6.58e2$$

$RBTL_{ss}$ = Risk-based target level in surficial soil [mg/kg] = 6.58e2

ii. Subsurface

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_i}{IR_{ai} \times ET_{in} \times ED \times EF}$$

$$RBTL_{ai} = \frac{1 \times 70 \times 25 \times 365 \times 0.0017}{1.5 \times 10 \times 25 \times 250} = 1.158e-2$$

$RBTL_{ai}$ = Risk-based target level in indoor air [mg/m^3] = 1.16e-2

$$RBTL_{si} = \frac{1.16e-2}{1.41e-2} = 8.215e-1$$

$RBTL_{si}$ = Risk-based target level for indoor inhalation of vapors from subsurface soils [mg/kg-soil] = 8.21e-1

iii. Groundwater

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$RBTL_{wi} = \frac{1.16e-2}{4.79e-3} = 2.42$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 2.42

TIER 2 EXAMPLE PROBLEMS

Scenario:

Complete routes of exposure include:

1. Indoor inhalation from soil
2. Indoor inhalation from groundwater

An aerial depiction of the contaminated area in question is shown below.

The impacted are is 20ft by 12 ft, and depth to groundwater is 15ft. Depth to impacted soil is 7ft.

Following a Tier 1 evaluation, site investigation indicated the following Tier 2 parameters:

$\theta_T = 0.25$
$\theta_{ws} = 0.20$
$\theta_{as} = 0.05$
$L_{GW} = 20ft = 609.6cm$
$L_S = 10ft = 304.8cm$
$h = 0.001$

Also assume the following:

- $\theta_{wcrack} = \theta_{ws}$, $\theta_{acrack} = \theta_{as}$, $\theta_{wcap} = 0.9 \times \theta_T$, $\theta_{TS} = \theta_T$, $\theta_{acap} = \theta_{TS} - \theta_{wcap}$

- If wind direction is not constant and known over the contaminated site, the length of soil source area parallel to wind direction (W_a) may be taken as:
$$W_a = \sqrt{\text{total area of soil source}} = \sqrt{AxB} = 9.165\,ft$$
- Similarly, the length of groundwater source area parallel to the wind direction (W_{ga}) may be taken as:
$$W_{ga} = \sqrt{\text{total area of groundwater source}} = \sqrt{WxY} = 17.32\,ft$$

All other parameters used in the following Tier 2 evaluation are the same as those used previously in the Tier 1 evaluation.

Contaminant: Benzene
Receptor: Commercial Worker

1. Indoor inhalation from soil
   a. Carcinogen

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{TR \times BW \times AT_c \times 365}{IR_{ai} \times ET_{in} \times ED \times EF \times SF_i}$$

$$RBTL_{ai} = \frac{1e\text{-}6 \times 70 \times 70 \times 365}{1.5 \times 10 \times 25 \times 250 \times 0.029} = 6.578e-4$$

$RBTL_{ai}$ = Risk-based target level for indoor inhalation of air [mg/m^3-air] = 6.578e-4

$$VF_{sesp} = \frac{\frac{H \times \rho_s}{[\theta_{ws} + (K_s \times \rho_s) + (H \times \theta_{as})]} \times \left[\frac{D_s^{eff} / L_s}{ER \times L_B}\right]}{1 + \left[\frac{D_s^{eff} / L_s}{ER \times L_B}\right] + \left[\frac{D_s^{eff} / L_s}{(D_{crack}^{eff} / L_{crack}) \times h}\right]} \times 10^3$$

$$D_s^{eff} = D^a \times \frac{\theta_{as}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{ws}^{3.33}}{\theta_T^{2.0}}$$

$$D_{crack}^{eff} = 9.30e-2 \times \frac{0.05^{3.33}}{0.25^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.2^{3.33}}{0.25^2} = 7.284e-5$$

D_s^{eff} = Effective diffusion coefficient in soil based on vapor-phase concentration [cm^2/s] = 7.28e-5

$$D_{crack}^{eff} = D^a \times \frac{\theta_{acrack}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^{2.0}}$$

$$D_{crack}^{eff} = 9.30e-2 \times \frac{0.05^{3.33}}{0.25^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.2^{3.33}}{0.25^2} = 7.284e-5$$

D_{crack}^{eff} = Effective diffusion coefficient through foundation cracks [cm^2/s] = 7.28e-5

$$VF_{sesp} = \frac{\frac{0.228 \times 1.8}{0.2 + (0.661 \times 1.8) + (0.228 \times 0.05)} \times \left[\frac{7.28e-5/304.8}{0.00023 \times 300}\right]}{1 + \left[\frac{7.28e-5/304.8}{0.00023 \times 300}\right] + \left[\frac{7.28e-5/304.8}{(7.28e-5/15) \times 0.001}\right]} \times 10^3 = 2.019e-5$$

VF_{sesp} = Volatilization factor from subsurface soil to indoor (enclosed space) air [(mg/m^3-air)/(mg/kg-soil)] = 2.019e-5

$$RBTL_{si} = \frac{6.58e-4}{2.019e-5} = 32.59$$

b. Non-carcinogen

$$RBTL_{si} = \frac{RBTL_{ai}}{VF_{sesp}}$$

$$RBTL_{ai} = \frac{THQ \times BW \times AT_{nc} \times 365 \times RfD_i}{IR_{ai} \times ET_{in} \times ED \times EF}$$

$$RBTL_{ai} = \frac{1 \times 70 \times 25 \times 365 \times 0.0017}{1.5 \times 10 \times 25 \times 250} = 1.158e-2$$

$RBTL_{ai}$ = Risk-based target level in indoor air [mg/m^3] = 1.16e-2

$$RBTL_{si} = \frac{1.16e-2}{2.02e-5} = 5.74e2$$

$RBTL_{si}$ = Risk-based target level for indoor inhalation of vapors from subsurface soils [mg/kg-soil] = 5.74e2

2. Indoor inhalation from groundwater
    a. Carcinogen

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$VF_{wesp} = \frac{H \times \left[\frac{D_{ws}^{eff} / L_{GW}}{ER \times L_B} \right]}{1 + \left[\frac{D_{ws}^{eff} / L_{GW}}{ER \times L_B} \right] + \left[\frac{D_{ws}^{eff} / L_{GW}}{\left(D_{crack}^{eff} / L_{crack} \right) \times h} \right]} \times 10^3$$

$$D_{ws}^{eff} = (h_{cap} + h_v) \times \left[\frac{h_{cap}}{D_{cap}^{eff}} + \frac{h_v}{D_s^{eff}} \right]^{-1}$$

$$D_{cap}^{eff} = D^a \times \frac{\theta_{acap}^{3.33}}{\theta_T^{2.0}} + D^w \times \frac{1}{H} \times \frac{\theta_{wcap}^{3.33}}{\theta_T^{2.0}}$$

$$D_{cap}^{eff} = 9.30e-2 \times \frac{0.025^{3.33}}{0.25^2} + 1.10e-5 \times \frac{1}{0.228} \times \frac{0.225^{3.33}}{0.25^2} = 1.226e-5$$

D_{cap}^{eff} = Effective diffusion coefficient through capillary fringe [cm^2/s] = 1.23e-5

$$D_{ws}^{eff} = (5 + 295) \times \left[\frac{5}{1.23e-5} + \frac{295}{7.28e-5} \right]^{-1} = 6.728e-5$$

D_{ws}^{eff} = Effective diffusion coefficient between groundwater and soil surface [cm^2/s] = 6.73e-5

$$VF_{wesp} = \frac{0.228 \times \left[\frac{6.73e-5/609.6}{0.00023 \times 300} \right]}{1 + \left[\frac{6.73e-5/609.6}{0.00023 \times 300} \right] + \left[\frac{6.73e-5/609.6}{(7.28e-5/15) \times 0.001} \right]} \times 10^3 = 1.536e-5$$

VF_{wesp} = Volatilization factor from groundwater to indoor (enclosed space) air [(mg/m^3-air)/(mg/L-H_2O)] = $1.54e-5$

$$RBTL_{wi} = \frac{6.58e-4}{1.54e-5} = 4.283e1$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 4.28e1

b. Non-Carcinogen

$$RBTL_{wi} = \frac{RBTL_{ai}}{VF_{wesp}}$$

$$RBTL_{wi} = \frac{1.16e-2}{1.54e-5} = 7.532e2$$

$RBTL_{wi}$ = Risk-based target level for indoor inhalation of vapors from groundwater [mg/L-H_2O] = 7.53e2

Thus the SSTLs for benzene are:

Soil: 32.59 mg/kg
Groundwater: 42.8 mg/L